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Description

PIPE ARRANGEMENT FOR A HEAT EXCHANGER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation patent application of International Application No. PCT/SE02/00958 filed 17 May 2002 which was published in English pursuant to Article 21(2) of the Patent Cooperation Treaty, and which claims priority to Swedish Application No. 0101798-7 filed 21 May 2001. Both applications are expressly incorporated herein by reference in their entireties.

BACKGROUND OF INVENTION

TECHNICAL FIELD

[0002] The present invention relates to an arrangement in a pipe joint for a heat exchanger also termed a recuperator that is adapted for use with a gas turbine for stationary use in a small scale combined power and heating plant or for

mobile use in a vehicle.

Background Art

[0003] A heat exchanger of the type may be used in, for example, a combined power and heating plant, for mobile use or in a reserve power station. For many such applications it is of vital importance that the recuperator is designed in such a way that is as efficient as possible, while minimizing weight and dimensions. The recuperator may, for instance, be made up of a plate heat exchanger comprising a number of plates manufactured from very thin sheet metal, generally having a thickness of about 0.1 mm. The plates are provided with corrugations in a known manner, whereby they are stabilized relative to each other in a wave shaped pattern. Spaces between the corrugations will then form flow channels for a heat emitting medium and a heat-absorbing medium. If a gas turbine is used, the heat-emitting medium is combusted gases leaving the turbine, while the heat-absorbing medium is usually air.

[0004] As the heat emitting and absorbing media may have a relatively high temperature, problems may arise in tubing and pipe joints of such systems. When starting a plant using a gas turbine, the temperature in the component parts will rise from ambient temperature, for example 20°C, to

temperatures in excess of 600°C. This usually entails large thermal loading due to heat expansion in different parts of the system.

[0005] At pipe joints between two sections of a heat exchanger, or between a source of heat and the heat exchanger, for instance between a gas turbine having exhaust gases requiring cooling, it may therefore be necessary to absorb forces that arise due to the fact that the heat exchanger packet and the pipe joint are very likely to have different coefficients of heat expansion. For this reason, welded or soldered joints in pipe systems without the capability of absorbing thermal loading are totally unsuitable, as repeated thermal loading will quickly give rise to cracks and leaks. Corresponding problems will also arise should mechanical joints, such as bolted connections, be used.

[0006] Hence one problem is to achieve a pipe joint that can be deformed in order to absorb thermal loads without being damaged. Depending on the positioning and assembly of the pipe joint, it may have to absorb movement in both axial and radial direction, in relation to the main axis of the pipe joint.

[0007] A further problem is the fit of such a pipe joint between two fixed points, where variations in fit and tolerance be-

tween the component parts of the heat exchanger may sometimes occur. In such cases it is also desirable to have a pipe joint that is deformable in several directions.

[0008] It is also desirable to be able to assemble such pipe arrangements economically, as known solutions are often complicated and expensive.

SUMMARY OF INVENTION

[0009] The purpose of the current invention is to eliminate known problems associated with existing solutions, thereby fulfilling the desired objectives of an improved pipe arrangement for a heat exchanger, as well as providing a simple and inexpensive arrangement for these purposes.

[0010] The intended purposes of the present invention are achieved by means of a pipe arrangement for heat exchangers including a pipe joint comprising (including, but not limited to) a number of corrugated plates. Each plate has a first edge part opposite a second edge part and a third edge part opposite a fourth edge part. Between the corrugated plates, first and second flow channels are provided and a heat-emitting medium flows through every alternate channel and a heat-absorbing medium flows through every other alternate channel. According to one

embodiment of the invention, the heat exchanger can co-operate with a gas turbine.

[0011] The heat exchanger is provided with an outgoing collecting channel for the heat emitting medium that is placed at one side of the heat exchanger and is connected to an outlet section of a combined inlet and outlet pipe joint for the heat emitting and heat absorbing media by means of a pipe section. The outlet pipe joint is placed at a distance from the side, and the pipe section comprises a substantially straight section with at least one straight sub-section, wherein a first sub-section is elastically deformable in both its axial direction and in all directions transverse to the axial direction, and a second sub-section is partially curved. The pipe section has a central load-absorbing through-member, the ends of which are attached on the outside of the pipe section. In this manner (whereby) the inlet end of the straight section is connected to the collection channel and the second sub-section is attached to the outlet pipe joint. The load-absorbing member is arranged to take up and balance forces caused by thermal movements in the heat exchanger packet and the pipe system. This solution is used in such cases where the thermal expansion in the heat ex-

changer packet and the pipe system is not the same. The properties of the member can be adapted by selection of material and/or dimension. An example of a material is a bar made from alloyed steel, having a suitable diameter.

[0012] Attachment of the load-absorbing member can be achieved by means of a suitable mechanical connection, such as a bolted connection. The ends of the element pass through openings in the pipe system at those points where the main axis of the straight section intersects the walls of the pipe system. Some machining may be required to achieve a flat surface around the openings, against which surfaces nuts or similar connectors can be tightened in order to clamp the ends of the element. In those cases where the pressure of the medium in the pipe system exceeds the ambient pressure, it may advantageous to attach the element by welding or soldering. The latter alternative minimizes the risk of leaks in the joints.

[0013] The elastically deformable first pipe section may for instance comprise a substantially cylindrical pipe, the walls of which have a corrugated cross-section in the axial direction of the pipe. Such an embodiment can, as a rule, entail certain flow losses. In order not to limit or disturb the flow through the pipe joint, the average diameter (that

is, the average of the inner and outer diameters of the corrugations), should be larger than the inner diameter of the adjoining second pipe section. Preferably, the inner diameter of the deformable first pipe section, corresponding to the smallest diameter of the corrugated section, is equal to the inner diameter of the second pipe section. The cross-section of the corrugated section may be varied depending on the size and direction of the thermal movements to be absorbed. One example of a suitable shape is a sinusoidal cross-section, where the amplitude and wavelength can be varied to give the desired properties with respect to deformability in the axial and radial directions.

[0014] In addition, the straight section can be connected directly to the collection channel, or indirectly via a further, curved third sub-section. The first alternative may be used if, for instance, it is desirable to angle the straight pipe section relative to the outlet pipe joint.

[0015] According to a further embodiment of the invention, the second sub-section is a curved pipe section, whereby the load-absorbing element is attached at the outer wall of the pipe section at a point where the main axis of the straight section intersects the major radius of curvature of

the curved pipe section.

[0016] According to a further embodiment, the second sub-section is a T-pipe section, whereby the load-absorbing element is attached at the outer wall of a closed end of the transverse section of the T-pipe section, at a point where the main axis of the straight section intersects the closed end.

[0017] It is also possible to provide the T-pipe section with a deformable fourth section in connection with its closed end, which section is deformable in its axial direction. A suitable use for this solution is when the thermal expansion of the heat exchanger packet and the pipe system differs.

[0018] It is also possible to vary the relative positions of the different sub-sections. According to one embodiment the straight section can be provided with a further, straight fifth sub-section, positioned between the deformable second sub-section and the curved second sub-section. According to a further embodiment, the deformable second sub-section can be positioned between the straight fifth sub-section and the curved second sub-section. In this way, the fifth sub-section can be used as an extension for adjusting the total length of the pipe section. Theoretically, the deformable first sub-section can be extended to

any length within the available space for the first sub-section. Its length is adjusted to enable absorption of a predetermined change of length in the axial direction of the pipe system and to enable a certain movement in the radial direction. Because the sub-section is elastically deformable, it can only absorb movements and not forces caused by thermal expansion in the other sections of the pipe system, or in the heat exchanger. The dimensions of the deformable sub-section are instead limited by factors such as the pressure in the flowing medium.

[0019] A suitable position for the straight section is so that an imaginary extension of its outer periphery in the direction of flow of the medium is radially separated from the outer periphery of the outlet pipe joint. Apart from this limitation, the straight section can be positioned at any desired angle between the main axis of the straight section and a straight line corresponding to the position of the main axis when the outer periphery of the straight section touches the outer periphery of the outlet pipe joint.

[0020] In addition, the curved, second section can be connected either radially or tangentially to the outlet pipe joint. The choice of connection is made dependent on the shape of the outlet pipe joint and the desired flow in the outlet

section. A tangential connection may for instance impart a helical flow in a desired direction. In order to control the flow in the curved section further, the connection to the outlet pipe joint may be directed in the main direction of flow of heat absorbing medium through the outlet pipe joint. This can be achieved by, for instance, aligning the curved section at a suitable angle relative to a radial plane through the outlet pipe joint.

[0021] If a single connection between the collection channel and the outlet pipe joint should prove to be insufficient, an additional embodiment allows the collection channel to be provided with two separate pipe sections, preferably one connection from either end of the collection channel to the outlet pipe joint.

[0022] An advantage of the pipe system described above is that it can be largely assembled using simple standard components. The straight section can be connected directly to the collection channel, or via an ordinary L-section with a desired radius of curvature. Apart from a straight sub-section, the straight section is provided with a deformable sub-section that is preferably corrugated. Such a corrugated section is manufactured by, for instance, rolling for metallic materials, injection molding for plastic materials

or winding for composite materials. The resilience to deformation of the deformable section is determined by, apart from the material, the relative distance between corrugations in the axial direction, amplitude in radial direction, and the thickness of the material. These variables are selected with respect to the desired diameter of the pipes, the maximum deformation caused by thermal loading, and the temperatures and pressures to be handled by the pipes.

[0023] The substantially curved section can either be made from a standard T-section or L-section, where the radius of curvature is selected to achieve the radial or tangential connection with the outlet pipe joint. Hence, the cost of such a pipe system can be kept at a very reasonable level.

[0024] The material used for the pipe arrangement is best chosen with respect to the field of application of the heat exchanger; that is, the type of heat emitting and absorbing medium, and the temperatures and pressure to which the pipe arrangement will be subjected. High temperatures and pressures will preferably require metallic materials, such as steel or aluminum of suitable thickness and quality, while lower temperatures and pressures may allow the use of plastic pipes. Corrosive media may require particu-

larly resistant materials. Joining of metallic pipes is preferably done by welding or soldering, while plastic materials and composites may be joined by welding, melting or gluing. Mechanical connections, such as threaded connections, are also possible, but will at the same time give a more space consuming, complex and therefore more expensive solution.

[0025] In order to reduce heat losses between the collection channel and the outlet pipe joint, the pipe system may be provided with a heat insulating layer or a material encapsulating the pipes.

BRIEF DESCRIPTION OF DRAWINGS

[0026] In the following text the invention will be described with reference to a number of preferred embodiments and with regard to the accompanying schematic drawings in which:

[0027] Figure 1 is a cross-sectional view of a schematic representation of a recuperator that is provided with a combined inlet and outlet pipe joint configured according to the present invention;

[0028] Figure 2 is a plan view of a pipe connection configured according to the embodiment of Figure 1;

[0029] Figure 3 is a plan view of a variation of the pipe connection of Figure 1;

[0030] Figure 4 is a plan view of another variation of the pipe connection of Figure 1;

[0031] Figure 5 is a plan view of a pipe connection configured according to a second embodiment of the invention;

[0032] Figure 6 is a plan view of a variation of the pipe connection of Figure 5; and

[0033] Figure 7 is a plan view of another variation of the pipe connection of Figure 5.

DETAILED DESCRIPTION

[0034] Figure 1 shows a schematic representation of a recuperator comprising a heat exchanger packet 1 with a combined inlet and outlet pipe joint 2, 3 and a outgoing, first collection channel 4 with a pipe connection 5 between the collection channel and the outlet pipe joint 3. The combined inlet and outlet pipe joint 2, 3 comprises two concentric pipes forming channels for heat transporting media. The inner inlet pipe joint 2 is connected to a source of heat emitting medium, which in the illustrated case is combusted exhaust gas from a gas turbine. The mass flow of heat emitting medium 6 flows through the heat exchanger in which a large portion of its heat energy is emitted to a heat-absorbing medium, which in this case is air. The heat-absorbing medium is collected in the outgo-

ing, first collection channel 4 whereby the flow 7 is directed out through a pipe connection 5 to the outlet pipe joint 3 towards the gas turbine.

[0035] A first embodiment of the pipe connection 5 is shown in Figure 2. According to this example, the pipe connection 5 comprises a straight first sub-section 10, a curved second sub-section 11, a curved third sub-section 12 and a straight fourth sub-section 13. The curved second sub-section 11 is connected to an inlet 8 on the outlet pipe joint 3, while the curved third sub-section 12 is connected to the collection channel 4. A straight pipe section including the deformable first subsection 10 and the straight fourth sub-section 13 are placed between the curved sub-sections 11, 12. These sub-sections are welded or soldered together to make an assembled pipe system.

[0036] The deformable sub-section 10 is made up of a corrugated pipe that can be deformed elastically by expansion or compression in its axial direction, and be deflected in its transverse direction. This allows the sub-section 10 to absorb movements caused by forces imposed on the pipe system when it is subjected to temperature variations, particularly during start-up of the plant when the temperature may rise from ambient temperature to about 650°C.

The length of the sub-section is adapted to the axial and lateral forces it is required to absorb, as well as to the amount of transverse deformation needed to enable fitting of the sub-section assembly. At temperatures as high as in the current case, the thermal expansion of the component parts making up the heat exchanger may be about one percent which causes correspondingly high thermal loads.

[0037] The length of the straight fourth sub-section 13 is dependent on the distance between the connection on the collection channel 4 and the inlet 8 on the outlet pipe joint 3. If the distance is short enough, the straight fourth sub-section 13 can be eliminated. It is also possible to eliminate the curved third sub-section 12 if it is possible to connect the straight pipe section directly to the collection channel.

[0038] In order to balance the forces in the pipe system, the system is provided with a central, uniting load-absorbing element 14. The element extends along the main axis of the straight pipe sections 10, 13 and comprises a bar of a material having suitable thermal expansion properties. In order to minimize the effect on the flow through the pipe system, the element 14 should be dimensioned to be as

small a diameter as possible. According to the current embodiment, both ends 14a, 14b of the element 14 passes through the respective curved sub-sections 11, 12. The load-absorbing element 14 is attached to the outside of the pipe section at the points where the main axis A of the straight section intersects the major radii of curvature R of the curved pipe sections. Adjacent these openings a shoulder 15, 16 has been welded onto the outer surfaces of the curved sub-sections 11, 12 in order to form contact surfaces for attachment devices in the form of nuts. The nuts are tightened in order to clamp the load-absorbing element, the ends 14a, 14b of which have been provided with threads.

[0039] According to a further embodiment, the load-absorbing element 14 can be welded to the pipe sections at its ends. In the case of the embodiment shown in Figure 2, this presumes that the load-absorbing element 14 and a corresponding section of the heat exchanger between the attachment points of the element have the same rate of heat expansion.

[0040] Figure 3 shows an alternative version of the first embodiment. According to this version, a longer pipe section can be achieved by not aiming the straight pipe section in the

direction of the outlet pipe joint 3. If necessary, it is possible to extend the pipe section even further, by placing an additional straight sub-section between the curved second sub-section and the inlet 8 of the outlet pipe joint 3. This embodiment also shows a radial connection of the pipe system onto the outlet pipe joint 3.

[0041] Figure 4 shows a further alternative version of the first embodiment. According to this version, a shorter pipe section has been achieved by aiming the straight pipe section 10, 13 so that its outer periphery virtually touches the periphery of the outlet pipe joint 3. This embodiment shows a tangential connection of the pipe system onto the outlet pipe joint 3. This will give the connection a more complex shape, but this may be outweighed by advantages in the way of improved flow through the outlet pipe joint.

[0042] According to the first embodiment, the heat expansion in the heat exchanger and in the pipe system, with its load-absorbing element, occurs at the same rate. If this is not the case, the pipe system in general, and the load-absorbing element in particular, will be subjected to large loads. Figure 5 shows a second embodiment of the invention that eliminates this problem by providing the curved

second sub-section with an extension 17, which in turn is provided with a further straight, deformable fifth sub-section 18. The extension 17 is welded or soldered onto the curved second sub-section 11, together with the deformable sub-section 18 and an associated closing end section 19. The load-absorbing element 14 is extended through an opening in the curved sub-section 11 and the end section 19, onto which it is clamped with a nut 20 in the same way as described above. This arrangement allows heat expansion of the load-absorbing element, the pipe system and the recuperator at different rates. The straight first sub-section 10 will then be deformed by thermal loads between the attachment points in the collection channel 4 and the outlet pipe joint 3, while the straight fifth sub-section 18 will be deformed by thermal loads between the assembled pipe system 10-12 and the load-absorbing element 14. This embodiment is shown in more detail in Figure 6, which shows an example of a radial connection of the curved second sub-section onto the inlet 8 of the outlet pipe joint 3.

[0043] According to a further, embodiment the load-absorbing element 14 is welded to the pipe sections at both its ends. In the case of the embodiment shown in Figure 3, the de-

formable fifth sub-section 18 allows for heat expansion of the load-absorbing element 14 and a corresponding section of the heat exchanger between the attachment point of the element at different rates.

[0044] Figure 7 shows an alternative version of the second embodiment. According to this embodiment, the curved sub-section 11 and the extension 17 have been replaced by a T-pipe 21. The transverse section 22 of the T-pipe 21 is arranged as an extension of the straight section 10, 13, where one end of the transverse section is attached to the straight first sub-section 10 and its other end is provided with a closing end section 19 with an opening for the load-absorbing element 14, as described above (Fig. 5). The T-pipe has a post 23 that is connected to the outlet pipe joint 3 via an inlet 24 shaped to create a tangential connection.

[0045] The flow through the pipe system, according to Figure 7, is only marginally disturbed by the T-pipe 21. The factor that has the greatest influence on the flow is the inner radius (r) at the junction between the inlet into the transverse section 22 and the outlet through the post 23 of the T-pipe.

[0046] In addition to the radial and tangential connections de-

scribed above, the flow into the outlet pipe joint 3 can be influenced by the angle of the connection 8, 11, 24 relative to a radial plane through the outlet pipe joint 3. Apart from the possibility to angle the entire straight section by connecting it directly to the collection channel, as described above, it is also possible to cut off part of the curved third sub-section 12 to achieve a desired angle. An alternative way to give the connection 8, 11, 24 a desired angle relative to the radial plane is to rotate the curved second sub-section 11, or, when applicable, the T-pipe around the main axis of the straight section 10, 13; i.e., around the load-absorbing element. It is of course also possible to achieve a desired angle by combining the above arrangements. By adjusting the position and angle of the connection, the flow can be directed into the outlet pipe joint as desired. In order to achieve a helical flow up through the arrangement, a connection aimed in a tangential direction is used, alternatively combined with a connection angled in the direction of flow of the medium. The attached Figures, however, only show connections in which the straight section is positioned in the radial plane, which in this case, coincides with the horizontal plane.

[0047] The invention is not limited to the above described em-

bodiments, but may be varied freely within the scope of the patent claims.